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ALTERNATIVE FUTURE SUPPLIES OF OIL IN CANADA AND THEIR COSTS

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1. INTRODUCTION AND MAIN CONCLUSIONS

The purpose of this working paper is to assemble available information about the future Canadian supplies of oil from various sources and their respective costs. While much of the information available on the potential sources of oil is tentative, the process of gathering and presenting estimates has been extended to include all of the sources because it is important to consider each of them relative to one another. As more information is made available, the estimates can be refined.

Sources of information used include documents and information published by government or regulatory agencies, the oil and gas industry, the media, and the Canadian Energy Research Institute.

Recent events in the world market for oil have been marked by large increases in the price of the commodity and by a growing insecurity of supply. This in turn has led to increased attention to the objective of oil self-sufficiency in Canada. It is therefore important to take stock of all Canadian potential sources of oil in order to see whether or not the objective is achievable. Information of this kind is not at present generally available.

Estimates of costs are also important and here again the information that is publicly available is sketchy and incomplete. Knowledge of costs of the various sources may well become critical in the light of the stated intention of the government to set the domestic price of oil according to the cost of developing alternative indigenous sources, rather than tying the Canadian price to the volatile world market. If domestic production is to be stepped up to displace imported oil, Canadians should know the approximate costs of oil from the alternative domestic sources in order that the least costly oil is produced first. Incentives could then be used to encourage particular activities leading to increases in the production of oil (e.g., frontier exploration, building of oil sands plants, etc.). Such measures have

traditionally been an integral part of the regulated market mechanism governing the oil industry in this country.

Five types of oil production will be considered: (i) conventional oil, (ii) frontier oil, (iii) oil from the oil sands, (iv) heavy oil, and (v) oil from enhanced recovery. Following a few general comments, estimates of future supplies are presented in a table showing five-year intervals between 1980 and 2000. A brief discussion of each of the five sources of oil will outline some of the uncertainties and problems peculiar to each of the five categories. Estimates of costs are also discussed.

The first main conclusion of this paper is that if the chosen base case prediction of future supply is fulfilled, other things unchanged, Canada will not reach complete self-sufficiency in oil between now and the end of this century, though a period of 92 to 93 percent of self-sufficiency is a possibility (see Figure 4). The second conclusion relates to the pricing of oil in Canada and to the cost of oil production. If the chosen base case is again assumed, all but one type of oil production (conventional oil) appear more expensive (i.e., uneconomic) relative to the current Canadian price of oil. For the objective of oil self-sufficiency this has a perverse influence since no incentive is provided for the producers to increase output, while at the same time consumers are encouraged to greater consumption by an artificially low price. The objectives of keeping the Canadian price of oil from rising and displacing all or a part of the imported oil by an increased domestic production are clearly not compatible.

2. GENERAL COMMENTS

It should be stressed at the outset that both the supply and the cost figures presented here are estimates, often chosen on the basis of wide-ranging projections made by various sources, and that they should, therefore, be interpreted cautiously. As with all projections, those made for the near future tend to vary less between sources relative to those made for a more distant time. Clearly, estimates for 1985, for example, can be viewed with relatively greater confidence than those pertaining to the year 2000.

While supply estimates will be shown for five-year intervals between 1980 and 2000, cost data are shown only for 1980. This is because all costs (unless stated otherwise) are expressed in constant 1980 Canadian dollars and are, therefore, still pertinent for application to subsequent years. To translate constant unit costs to current dollars for some chosen year in the future, one could use a projected national income deflator, an index of aggregate industry selling prices or some other index, thereby implicitly assuming that the producers' cost of supplying oil will be rising more or less at the same rate as the selected index. The producers' cost, however, may rise at a different rate because cost inflation as experienced by oil producers may proceed at a faster rate than that of the economy as a whole. (This could be caused, for example, by bottlenecks in the labour market or in the market for materials in the event that the construction periods of two or more major energy projects (e.g., oil sands plants) overlap.) A second reason, for which there is ample empirical evidence, is that the cost of finding new oil increases over time.[1] The finding cost of new reserves is an important component of the cost of supplying conventional, frontier and heavy oils (together with development and production or 'lifting' costs). It seems reasonable, therefore, that in order to arrive at a constant 1980

dollar cost for, say, 1985, one might have to escalate the appropriate 1980 figure by a chosen percentage per year depending on the anticipated industry cost inflation above the rate expected for the economy as a whole. This exercise has not been carried out here since expectations of the industry's cost inflation may differ and there will also be differences in the rate of cost increases for the various sources of oil. In any event, rates of increase should be subjected to sensitivity analysis (e.g., by using low, base and high rates).

There is one further point concerning the supply and the cost estimates discussed in this paper. While the supply figures are those of future production, the cost estimates are based on production today. At this time we have no reliable forecast of future domestic oil prices, but, more importantly, we lack estimates of the responsiveness of the oil supply from all five sources under consideration to such a price forecast. If future oil prices change significantly, particularly upward, it is expected that the supplies will change in the same direction.

The supply estimates are presented in Table 1 at the end of this section, while the estimates of cost are discussed in Sections 3 to 7, below, and shown in Table 2 in the last section. The supplies are expressed in terms of thousands of barrels per day and the costs in constant (1980) dollars per barrel of oil produced. It is convenient to view the cost per barrel as the supply price a producer must receive to undertake production, with producers recovering a portion of the total finding cost as well as development and production costs over each barrel produced, regardless of whether it is produced now or in the future. Such a price will, therefore, cover all the expenditures incurred by the producer (i.e., exploration, capital and operating outlays) and it also includes a return on investment. The supply price estimates that are made in this paper do not include taxes or royalties; and they are basically wellhead prices or, in the case of oil sands plants, prices at the plant gate. Taxes, royalties and transportation charges would have to be added to the supply prices in order to compare the cost of oil from various sources at the main consuming areas of Montreal or Toronto.

Table 1 shows the estimated potential future oil production from the five sources under consideration. The estimates are based on established reserves and on projected reserve additions. In Table 1, a single number has always been chosen as an estimate with the range indicating possible low and high extremes shown in brackets. The range shows the actual spread of the collected estimates; and the single figure (to represent a 'base' case) has been calculated as the simple average of all estimates except in the case of older estimates (more than three years), when more recent information was made to carry more weight.[2] Where no estimates or only single estimates were available, a question mark appears in the table to warn the reader of increased uncertainty. The following five sections discuss each of the ways of supplying oil in more detail.

TABLE 1

ESTIMATED OIL PRODUCTION FROM VARIOUS SOURCES
(thousands of barrels per day)

	(i)	(ii)	(iii)	(iv)		(v) Enhanced Recovery	
	Conventional Oil	Frontier Oil	Oil Sands	Heavy Oil Production	Heavy Oil Upgrading	Light & Med. Oil	Heavy Oil
1980	1,313 (1,230-1,343)	-	162 (150-188)	230 (88-230)	-	12 ? (8-24)	3 (0-8)
1985	824 (702-910)	90 (0-260)	238 (200-260)	161 (80-230)	50 ?	75 (17-174)	26 (4-87)
1990	752 (564-1,093)	453 (0-1,100)	541 (500-625)	176 (78-271)	75 (50-100)	210 (30-550)	58 (13-105)
1995	593 (396-945)	500 (0-?)	795 (708-975)	191 (85-304)	100 (50-150)	148 (19-346)	70 (21-126)
2000	150 (?)	?	898 (815-944)	170 (90-287)	?	27 (?)	135 (0-266)

3. CONVENTIONAL OIL

One of the main features of conventional light and medium oil production in the western Canadian sedimentary basin (here considered together with pentanes plus) is the low rate at which new oil reserves have recently been discovered and the generally declining production rates from existing reservoirs, using primary and secondary recovery processes. It is widely held that among the reasons for the low discovery rate is the lower profitability of oil exploration relative to natural gas, and the fact that we have had roughly three decades in which much of the search concentrated on oil. Since natural gas carries a lower royalty rate than oil, and producers have also shared in more profitable export contracts (where the price of gas is tied to the world price of oil), many companies have recently found the production of natural gas more attractive than exploration for oil.[3] Figure 1 compares rates of production and discovery of oil and natural gas during the 1970s. Even at the current Canadian domestic price of oil ($14.75/bbl), with the finding cost at the $8.00 per barrel level reached in 1979[4] there would be only a very small profit margin left after taxes and royalties were paid even if the search for oil was successful.

It has been mentioned that the cost of finding new oil is an important component of the supply price or the cost of producing a barrel of oil. Finding costs typically vary from year to year depending on the success of exploration. For the whole of Canada including offshore,[5] for example, the 30-year average finding cost for the period up to 1977, in current dollars, was $1.66 per barrel equivalent. This cost increased to $5.05 per barrel during the four years from 1973 to 1977.[6] The possibility of smaller reservoirs becoming increasingly more difficult to find implies that this component of the supply price of oil may further increase in the future.

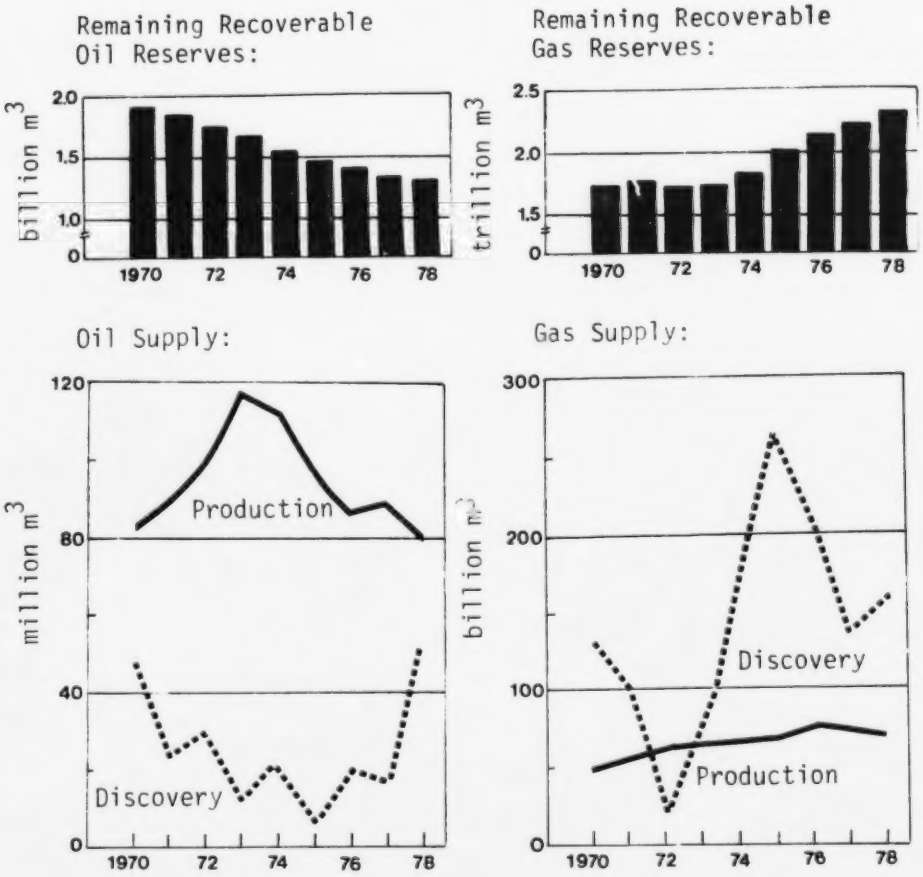

FIGURE 4.1: Production and Discovery of Oil and Natural Gas, 1970 - 1978.

SOURCE: The Calgary Herald, December 19, 1979.

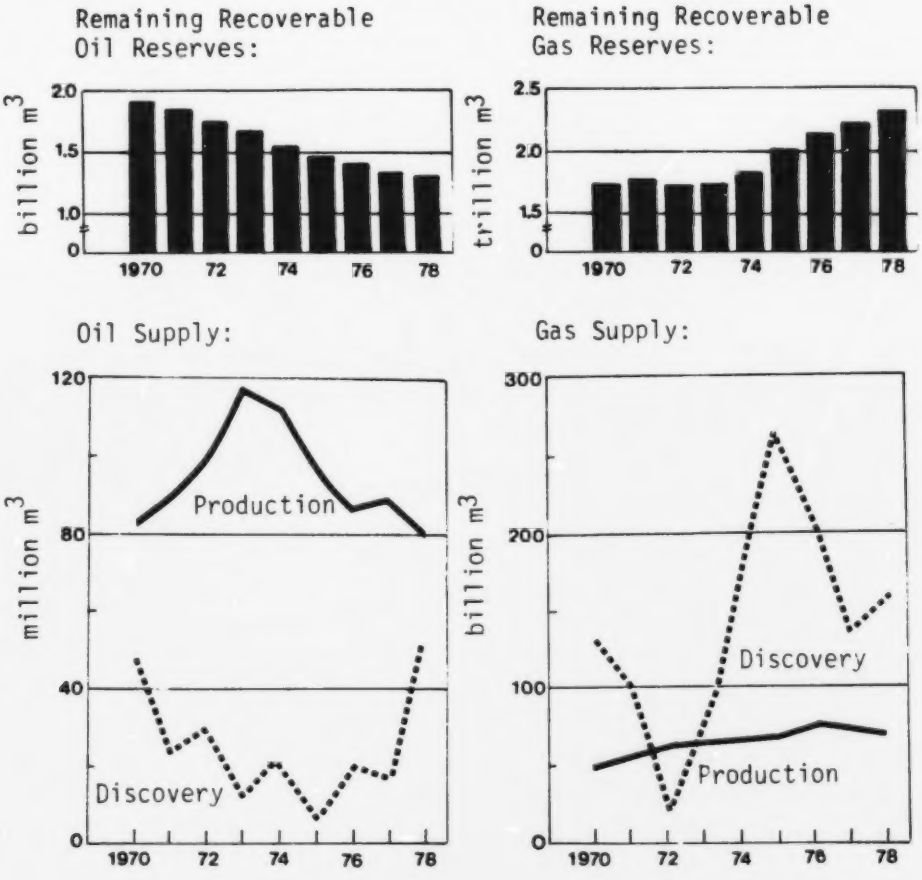

FIGURE 4.1: Production and Discovery of Oil and Natural Gas, 1970 - 1978.

SOURCE: The Calgary Herald, December 19, 1979.

Estimates of future supply (production) of conventional oil are largely uncertain because we are unsure of how oil producers would react to an increased domestic oil price and how successful any increased exploration would be. Although a direct relationship inevitably exists between the quantity of oil supplied (discovered and produced) and the selling price, there are long time lags between price changes and the time new oil is delivered to markets. Both the quantity of oil and the length of the lag are uncertain. It is clear, however, that a higher price will tend to increase the production of oil in three ways: (i) the percentage of oil in place recovered would increase through the application of improved levels of recovery; (ii) oil could be recovered from previously non-commercial discoveries; and (iii) new reserves could be found through successful exploration.

Looking at the supply estimates in the first column in Table 1, it can be seen that conventional oil production is expected to decline throughout the forecast period. The estimates are based on information published by government or regulatory agencies (EMR, NEB, ERCB and the Alberta Petroleum Marketing Commission--see bibliography), and information made available through published documents or through communications with industry sources. In general, estimates made by government or regulatory agencies appear on the lower end and those made by the industry are on the upper end of the range of available forecasts.[7] The estimates of potential future producibility include oil from established reserves and from predicted reserves additions in the western Canadian sedimentary basin. Estimates of the volume of future discoveries of oil vary among sources, but they basically depend on the particular view one takes with respect to the future development of domestic prices of oil, the response of production to it and the success of exploration. At present, for example, differences in estimates for oil production from western Canada result in part from differences of opinion regarding the potential of the West Pembina play. The base case estimate of the NEB used in Table 1 for instance includes 1.3 billion barrels of recoverable crude oil with a possible range of 0.9 to 2.9 billion barrels, with 0.5 billion barrels in the base case assumed to come from West Pembina.[8] The ERCB, whose

estimates are also included in Table 1, predicts that some 9 billion barrels of crude oil in place remains to be discovered but that only about 1.7 billion barrels (1.2 billion of light and medium oil and 0.5 billion of heavy oil) will be recovered by natural depletion and waterflood.[9]

It is possible to take a more optimistic or pessimistic view of the future production. The projected volumes of production using the extreme figures from brackets in Table 1 are shown in Figure 2. It is clear, however, that no matter which figures are used, the trend of future production is declining and only a truly major oil discovery could reverse it.

The supply price of the conventional oil has been estimated at $11.41 per barrel with possible extreme values of $7.78 and $15.04 per barrel (Table 2). As mentioned above, this is a wellhead price which does not include taxes or royalties, but it includes a return to all necessary factors of production. It is composed of three parts: the finding cost, the development cost and the production or 'lifting' cost. The most recent estimates of finding cost vary between $5.00 to $8.00 per barrel. Estimates of development cost, which include development drilling, land acquisitions and rentals, range between $1.66 and $3.70 per barrel; and those of production cost appear to fall within $1.12 and $3.34 per barrel.[10]

The range of supply prices given in Table 2 was derived by adding the corresponding ranges of all three cost components. With $7.78 and $15.04 thus obtained, a simple mean of $11.41 was chosen to represent the base case. The estimates of finding cost are current which means that the supply price ($11.41/bbl) will apply more appropriately to oil being discovered now and in the future, while the lower historical finding cost of conventional oil (moving average of some $3.30/bbl) would yield a supply price of between $6.08 and $10.34 per barrel for oil discovered in the past.

4. FRONTIER OIL

Frontier oil is a relative newcomer into the oil supply picture in Canada. No frontier oil for commercial purposes has so far been produced, but indications are that in the foreseeable future oil from the frontier areas may prove important for Canadian energy requirements and indeed for the objective of reaching oil self-sufficiency. By 'frontier' we mean all such areas, mainly offshore, where future oil production may take place. In particular, it is the Beaufort Sea, the High Arctic and the area off the East Coast.

It appears that the first frontier oil may come from either the Beaufort Sea or from off the coast of Newfoundland. These areas differ in their geography, geology, and their proximity to markets, all of which will be important in determining the supply price (including the cost of transportation) of their oil. But since no oil for commercial purposes has been produced thus far, both the cost and the supply estimates are that much more uncertain.

The uncertainty of the supply estimates of frontier oil can be observed in Table 1 where it will be noted that their range is relatively wide or simply undetermined. In 1985, for example, it is assumed that 90,000 barrels per day will be produced (60,000 bbl/day from Hibernia and 30,000 bbl/day from Beaufort Sea) with some additional production (up to 170,000 bbl/day more) being conceivable from either off the coast of Newfoundland or the Beaufort Sea. By 1990, it is expected that oil will flow from the Beaufort Sea (up to 900,000 bbl/day has been estimated)[11] as well as from Hibernia, and possibly other fields off the East Coast. No estimates have so far been available for output by the year 2000.

The greater uncertainty surrounding the frontier regions is understandable since little is known about the reserves, and the necessary technology is only beginning to be developed. Also, longer lead times will probably be experienced than in the case of conventional oil. It has been estimated that, depending upon the geography

and the nature of the hydrocarbon, three to fifteen years may be required from the date of discovery to the date of first production.[12]

As with conventional oil, the supply price of frontier oil will have three components: the cost of finding the oil, development drilling and rental charges, and the cost of actual production. The finding cost will again vary from year to year depending on the success of exploration. The year 1979 was relatively successful. Although Dome Petroleum's Kopanoar well in the Beaufort Sea has not been officially pronounced a commercial find, it tested encouraging amounts of oil. On the other hand, the Hibernia well off the East Coast (operated by Mobil on behalf of that company along with Chevron, Gulf, Petro-Canada and Columbia Gas Development) has been pronounced commercial, and the operators are expecting oil production to start between 1983 and 1985 and running until 1997 or 2000.[13]

The finding cost in the frontier region has also been increasing. Only rough estimates are available involving the discovery of not only crude oil but also natural gas and gas by-products, all expressed in terms of oil equivalent (on Btu basis). The average finding cost of this composite during 1947-1977 in the areas including the Arctic Islands, the Yukon, Northwest Territories, the Beaufort Sea and off the East Coast has been estimated at $1.47 per barrel of oil equivalent. The average between the years 1973 and 1977 for 'North Canada', however, was $2.16 per barrel equivalent, and in 1977, $4.02 per barrel.[14]

No reliable estimates are available of the breakdown between development and production costs, but it has been estimated that the wellhead supply price of a barrel of oil from either the Beaufort Sea or off the East Coast could be in the neighbourhood of $15.50 per barrel.[15] Adding and subtracting 20 percent from this figure (to obtain possible low and high extremes) yields a possible range for this supply price of $12.40 to $18.60 per barrel (Table 2).

The cost of bringing the oil from the producing to the consuming areas is much more significant in the case of frontier oil than conventional oil. Only very rough estimates are available of the transport charges between the main consuming areas of Toronto and Montreal and the potential offshore of Newfoundland or Beaufort Sea

developments. For example, the cost per barrel of oil brought to Toronto from offshore Newfoundland via conventional oil tanker and pipeline, has been estimated to be between $1.05 and $2.70, depending mainly on the size of the tankers and the length of yearly operating time. The cost of delivering Mackenzie Delta-Beaufort Sea oil to either Toronto or Montreal via an icebreaking tanker, on the other hand, could be between $4.40 and $6.15 per barrel. These costs can be compared to the pipeline tariff of about $0.85 per barrel between Edmonton and Toronto.

The frontier areas could contain more oil than indicated by the estimated figures for potential production in Table 1. The main questions are when will the reserves be discovered and whether or not both technology and economics will justify their early exploitation.[16] At the present time, frontier oil is uneconomic (e.g., $15.50 plus a transport tariff of, say, $1.85 per barrel of oil from the offshore of Newfoundland brought to Toronto yields a supply price, without taxes and royalties, of some $17.35 per barrel) as compared with the domestic wellhead price ($14.75/bbl). It is, however, less costly than imported oil at $CDN 29.90 per barrel to $43.02 per barrel.[17]

5. THE OIL SANDS

Synthetic crude oil produced from the raw bitumen found in extensive sand deposits in northern Alberta poses somewhat different problems than those associated with conventional oil. The basic difference is that the oil sands reserves are well known and hence the greatest uncertainty of the supply price of conventional oil--exploration cost--is eliminated and with it all the risks that go with searching for new oil. There is another element of risk, however, related to the technology of producing oil from the oil sands on a large scale. The Syncrude plant, for example, has been experiencing difficulties since September, 1978, when it began production. This sort of risk can be expected to be reduced, though perhaps not entirely eliminated, through improvements in the technology.

Although oil from the oil sands is more expensive than conventional oil, supplies from such sources can be more accurately predicted once the plants have been built. Also, the output of an oil sands plant will not tend to decline later in operating life as is inevitably the case in the conventional oil production due to the loss of natural reservoir pressure. In fact, the characteristics of an oil sands plant resemble more a manufacturing process than does conventional oil production.

A choice between conventional and synthetic oil production would be complicated. Although the potential quantity of synthetic crude producible from the Alberta oil sands is substantial and well known, other problems stand in the way of its rapid development; front-end costs are much higher than in the case of conventional oil production, lead times are long, the optimal scale of projects is much greater and there are environmental problems to consider. Also, the existing mining technology has been hampered by scale problems, and the technology of separating the oil from the sand uses a lot of energy. Yet the oil sands, tapped either by surface mining or in situ methods, must play an important role in future oil supply in this country.

The anticipated future supplies from the oil sands can be seen in Table 1. The supply figures reflect the progress in the construction of new plants and expected extensions of plants which either already exist (Suncor, Syncrude) or are at the advanced planning stage (Alsands, Imperial Oil). These figures are uncertain to the extent that they depend heavily on the negotiations between the operators and the two levels of government (provincial and federal) determining the tax and royalty payments and the price at which the oil will be sold.

A little more is known about the cost of oil sands production than in the case of frontier oil but not as much as about conventional oil. Only two oil sands plants have so far been constructed (Suncor and Syncrude) and two others are awaiting official approval (Alsands and Imperial's Cold Lake in situ project). The supply price per barrel has been estimated to be between $12.50 and $20.29. A simple mean of all estimates representing the base case is $17.08 per barrel, which is similar to the recently estimated cost per barrel of oil from the Alsands and Imperial's Cold Lake projects of about $17.10 and $17.75 respectively.[18] One important aspect of these costs or supply prices is the selection of the optimal size of a plant such that the unit cost of production will be the lowest. From the submissions to the NEB it appears that around 130,000 to 140,000 barrels per day is the first level of optimization and that increments above that are likely to be around 60,000 to 70,000 barrels per day. An optimal plant size would then consist of two or three independent units, each with an output of around 65,000 barrels per day.[19]

The cost estimates provided here must be viewed with uncertainty primarily because of the possibility of cost overruns during the construction period lasting some six years. If synthetic oil production is to make a mark on the Canadian oil supply schedule, the construction of future plants will have to be stepped up. This would create a major challenge for the economy as a whole but mainly for the area (Alberta) where the construction would take place. The possibility of building two or more of these plants simultaneously, or having their construction periods overlapping with other major projects in the area (e.g., pipelines), might cause serious shortages to develop in the labour market and the market for materials, which would mean

more rapidly rising prices. A careful scheduling of the plants will, therefore, be the key to holding the construction costs down and preventing delays and cost overruns.

The pricing of synthetic crude oil in Canada has recently become a contentious issue. The so-called 'Winnipeg Agreement' of February, 1975, which ensured the continuation of the Syncrude project, provided a guarantee for the operators that Syncrude's output would be sold at a world price, defined as the cost of imported oil landed at Montreal, plus a quality differential.[20] The federal government agreed to compensate refineries using synthetic crude oil as feedstock for the difference between the domestic wellhead price (now at $14.75/bbl) and the prevailing world price (as defined above and currently at $35.00/bbl). This subsidy is financed by a levy (the 'Syncrude Levy') on all oil products sold in Canada which at the present is $1.00 per barrel.[21] Both Syncrude and Suncor plants are selling their output in Canada at the world price, and it has been shown that if this policy had not been changed recently, the Syncrude Levy would have had to increase from the current $1.00 per barrel to $3.00 per barrel by 1985, to $10.00 per barrel by 1990, and to $37.15 per barrel by the year 2000.[22]

The Winnipeg pricing agreement also contained a 'force majeure' clause that allows either party to review and renegotiate the definition of 'world price' should OPEC oil prices rise to unexpected levels. On March 29, 1980, the federal government invoked the 'force majeure' and cancelled the world price guarantee. It is to be replaced by a 'blended oil price' which would be based on the cost of production of oil from various sources with provisions to be made for a return for each company's investment.[23] It should be noted that such a change is a move away from an ordinary (although a cartel-type) market pricing mechanism to a regulated pricing common with public utilities.

The new blended price is still, however, subject to upcoming fiscal negotiations between the federal government and the government of Alberta, but both Suncor and Syncrude plants will keep receiving the world price while these negotiations are in progress.

6. HEAVY OIL

As the production of conventional oil declines through the 1980s, heavy oil, much like synthetic crude oil, is likely to make up for a good portion of the decline. A further parallel between the heavy and oil sands oils is that substantial reserves of both are known to exist but the process of unlocking the oil is uncertain and expensive. In order to arrive at a product (refinery feedstock) comparable to conventional oil, heavy oil must first be extracted and then upgraded, which adds to the overall unit cost. To date, no heavy oil upgrading plant has been built in Canada. Of the roughly 230,000 barrels of heavy oil produced per day, some 120,000 barrels are exported to the U.S. where refining capacity exists, and the rest is used in Canada primarily for the production of asphalt. In order for heavy oil to be shipped through a pipeline, it must be mixed with light oil and even then, specially equipped refineries are left with large amounts of asphalt as a by-product. The reason why no heavy oil refining capacity exists in Canada is apparently the fact that, in spite of the reserves, no firm commitment to provide feedstock over the life of an upgrading plant has been made. But, to assure feedstock, the recovery processes must first be tested. This is underway in Alberta and especially in Saskatchewan, where a number of pilot projects run by various companies are currently in progress.

Considerations such as these raise uncertainty with respect to the production estimates in Table 1. The data are based on projections made by the NEB, ERCB, Alberta Petroleum Marketing Commission and industry sources, and they include production from existing oil reserves as well as oil from expected future discoveries extracted through primary recovery and waterflood. The production of upgraded heavy oil will depend on how fast the construction of upgraders can proceed. A heavy oil upgrading plant will again resemble a manufacturing plant and hence the question of an optimal producing capacity becomes critical. From the past proposals to build an upgrader it

appears that a plant consisting of one or two independent units each producing between 45,000 and 50,000 barrels per day of upgraded oil might be approaching size optimization.[24] Studies by at least one oil company suggested, however, that the capital cost per barrel of a 50,000 barrels-per-day plant would likely be between 15 and 25 percent higher than in a 100,000 barrels-per-day plant.[25] Whether or not the potential supply projection of upgraded oil will be fulfilled depends on the profitability prospects for the upgrading plants.

This brings us to the cost estimates of heavy oil production and upgrading. The sources of these estimates are the NEB, EMR, and the industry. The cost per barrel of produced (but not upgraded) heavy oil has been estimated to be between $6.55 and $12.65.[26] From this range of estimates a simple mean has been chosen to represent a base case figure of $8.95 per barrel. This is somewhat less than in the production of conventional crude which has higher finding cost.

A relatively large number of cost estimates of heavy oil upgrading are available, but since no upgrading has so far taken place in Canada, a greater element of uncertainty surrounds these numbers. The range of some ten estimates used in this paper is quite wide, beginning at a very low $2.37 per barrel and ending at $9.03 per barrel. There is a good reason for the variation. Since there are some eight recognized methods of upgrading heavy oil, cost estimates will correspondingly differ among them. The estimates differ due to the variations in both capital and operating costs of each individual technological process, but the different processes will also yield a product of different quality, depending on the amount of sulphur and nitrogen removal and other residue production.[27]

A base case figure can again be chosen from the above range of cost estimates for upgraded heavy oil. The simple mean of all estimates is some $5.60 per barrel. If we add to this cost the similarly derived figure for heavy oil production ($8.95/bbl), we obtain a possible base case estimate of $14.55 per barrel of upgraded heavy oil (the low and high values are then obtained by adding the $5.60 to the extreme values of heavy oil production). This is just under the current Canadian oil price of $14.75 per barrel, but since the supply

price does not include taxes or royalties, the production of upgraded heavy oil appears uneconomic on the basis of the present information.[28]

The production of upgraded heavy oil could, however, be made economic, depending on the tax and royalty payments which would apply to the production and the price at which the output is sold. The production certainly appears economic if one assumes a rising price of oil. If increased domestic production of oil is the objective, a higher Canadian price would provide the needed incentive to increase heavy oil production and to build the necessary upgrading facilities.

7. ENHANCED RECOVERY

Enhanced recovery is defined here as all recovery methods beyond primary and secondary production. Thus enhanced recovery is taken to include all tertiary (or 'exotic') recovery methods such as miscible gas, chemical or thermal, and not secondary methods such as waterflood. This, or any other definition of enhanced recovery, will necessarily cause difficulties in forecasting supply and costs since producers can skip secondary recovery methods on the way from primary to enhanced recovery, or move back and forth between enhanced and primary recovery. This is dictated by the geological conditions of each reservoir and so it may be difficult to correctly estimate the incremental amounts of recovered oil attributable to enhanced recovery as well as the cost such recovery will entail. For this reason the supply estimates may be conservative. But estimates of both cost and output are essential since enhanced recovery methods, although expensive, are viewed with optimism for future supply of oil in this country.

Although the quantity of heavy oil reserves is very large in Canada, primary production methods will typically recover only between 3 and 5 percent of the oil. Application of waterflood will increase this percentage to between 7 and 11 percent while tertiary recovery may result in an average of 30 percent recovery rate.[29] For conventional light and medium oil reserves, the recoverable amount by primary and secondary methods is higher, but even there it is only about 32 percent. This may be raised, on average, to between 40 and 44 percent by the application of tertiary recovery methods.[30] It is these estimates of improved oil recovery factors that have made enhanced recovery an attractive alternative of future potential supply of oil.

The estimates of potential future oil production from enhanced recovery of both light and medium oil, and of heavy oil are shown in Table 1. The numbers are based on data published by the ERCB, NEB, industry sources and a recent study by the Canadian Energy Research Institute.[31] Being a relatively new source of oil, future projections

of production are very uncertain and consequently differ a great deal between sources. The reasons for the differences in forecasts include the following: the definition of enhanced recovery may vary; forecasts may be based on known reserves only or include reserves yet to be discovered; the technology of exotic oil recovery is not fully proven and forecasts, therefore, may vary with the degree of confidence placed on technological progress; and, last but not least, the method of forecasting employed may differ between sources.

Different forecasts could vary a great deal as a result of the size of the reserves to which enhanced recovery methods are to be applied. Predictions of future supplies from enhanced recovery projects will be lower if based on presently known reserves only, than if new reserves, expected to be found in the future, are included. While some sources base their forecast on presently known reserves only, the ERCB forecast of future productivity of both the light and medium, and the heavy crude oil categories for Alberta, for example, is based on "proved recoverable reserves remaining as of 31 December 1977, and expected reserves growth, resulting from appreciation of presently proved reserves, primary depletion and waterflooding of new discoveries, deferred abandonment of existing pools and exotic recovery application to both proved and undiscovered oil-in-place."[32] On the other hand, the CERI forecast by Prince, which is the most recent of all available sources, is based on a pool-by-pool analysis of known reservoirs only.

The method of forecasting employed and the forecaster's view of technological advancement will certainly be another factor influencing the results. It is the view of the present writer that forecasts assuming technological progress introduce an additional element of uncertainty which, especially in the case of a short of medium-term forecast, might not be desirable and justified.

The large variations between the estimates used in Table 1 can be seen from the numbers in brackets which list the extreme values for each of the five-year periods listed. From this extreme range, a simple mean has again been calculated to illustrate what may be a base case prediction of the supply of oil from enhanced recovery projects. Much of the difference in supply estimates originates in the way future

domestic oil prices are expected to change and in the cost projections for enhanced recovery schemes. Figure 3 shows one estimate of the expected impact of price on enhanced recovery potential in Canada. Prince suggested that, compared with the roughly unitary elasticity of supply of conventional oil, enhanced oil recovery is about twice as responsive to price increases. That is, if the price of oil raises by, say, 10 percent, enhanced recovery output can be expected to increase by 20 percent.[33] Prince also points out the physical limitations of the enhanced recovery potential. Based on existing reservoirs only, he asserts that the maximum recovery potential in Canada is limited to 3.1 billion barrels and that a greater recovery would require basic technological advancement of the various production processes currently in use.[34]

Estimates of the lifting cost of oil from enhanced recovery schemes also vary a great deal. For light and medium crude oils the range could be between $5.00 and $16.97 per barrel.[35] The range is wide because different recovery methods will not be equally costly. For example, it has been estimated that oil recovered through miscible gas flooding will be more expensive (in the upper end of the range) than when chemical recovery methods are employed (in the lower end), while thermal oil recovery, used mostly in the production of heavy oil, has an estimated supply price between $5.57 and $11.66 per barrel.[36] This means that in the case of heavy oil, when taking an average of all lifting cost estimates ($7.62/bbl) and adding to it the similarly chosen cost of heavy oil upgrading ($5.60/bbl), we arrive at a possible base case supply price of $13.22 per barrel for a light crude oil equivalent.[37] Although this is below the current Canadian price ($14.75/bbl), no taxes or royalties are included and thus for the purpose of this example of base case estimates at least, the economic viability of production would depend on the actual taxes and royalties producers would be required to pay. In the case of enhanced recovery of light and medium crude oil, it appears that the use of miscible gas flood will have a wider use than chemical recovery[38] and that, therefore, the supply price might be closer to the upper end of the estimated range ($16.97/bbl). This puts the supply price in the vicinity of the domestic oil price but again, no taxes or royalties have been included.

8. SUMMARY COMMENT

This paper has brought together available estimates of both supplies of oil from five different sources and their respective costs. The results have been summarized in Tables 1 and 2 respectively. Although it is not recommended that the two tables be used together in attempts to draw a conventional supply curve (for reasons explained in Section 2 above), the information contained in the tables can stand on its own and be useful in the examination of oil self-sufficiency in Canada.

We can add the projected future supplies from the five sources from Table 1 and compare them with a standard demand forecast for the same time horizon to find out when (if at all) self-sufficiency might be achievable. This is done in Figure 4. It can be seen there that given the supply forecast from Table 1 (the low and high extremes and an arbitrarily selected base case), everything else unchanged, only if the high case is fulfilled would Canada become self-sufficient in oil. And even then, if all excess to domestic consumption is exported, it would only be for a period of time roughly between 1986 and 1997. Should the base case projection come true, then only about 61 percent self-sufficiency will be achieved by 1985 and a maximum of 92 percent by 1990 and 1995 with the percentage dropping off again after that year. The low case presents a rather unpleasant prospect for the objective of self-sufficiency.

It should be emphasized, however, that important changes may occur in the future and that, for example, unexpected discoveries of large and accessible deposits of hydrocarbons or advances in technology may significantly alter the projections.

The main purpose of Table 2 is to bring together available cost information. The table should be read together with Sections 3 to 7, where the cost data are qualified and discussed in some detail. Given these data, all expressed in terms of the supply price of oil at the wellhead or plant gate, one can attempt to rank the various

TABLE 2

ESTIMATED SUPPLY PRICES OF OIL FROM VARIOUS SOURCES
(1980 $/bbl)

Type of Oil	Supply Price	
	Base Case	Low and High
i) Conventional oil	11.41	7.78 - 15.04
ii) Enhanced recovery		
Light & medium oil	5.00 - 16.97	5.00 - 16.97
Heavy oil	7.62	5.57 - 11.66
Upgraded heavy oil	13.22	11.17 - 17.26
iii) Heavy oil		
Production	8.95	6.55 - 12.65
Upgrading	5.60	2.37 - 9.03
Upgraded heavy oil	14.55	12.15 - 18.25
iv) Oil sands	17.08	12.50 - 20.29
v) Frontier oil	15.50	12.40 - 18.60

SOURCE: See text.

alternatives. For the base case, conventional oil appears to be the cheapest to supply ($11.41/bbl), while oil from the oil sands is the most expensive ($17.08/bbl). Oil from enhanced recovery of light and medium oil appears comparable to upgraded heavy oil, both of which are only slightly more expensive than primary and secondary recovery of conventional oil, but cheaper than frontier oil and oil from the oil sands. For the base case, therefore, it is suggested that given the supply price estimates, everything else unchanged, conventional oil followed by oil obtained from enhanced recovery schemes and upgraded heavy oil should be the first sources to be tapped before oil from the oil sands and the frontier regions come on stream. With about one quarter of domestic demand for oil being supplied by foreign sources, however, the question of security of supply may override this simple cost-efficiency criterion. As pointed out in Section 2 above, it may be imperative that in order to increase supply security, more expensive but certain domestic sources (e.g., the oil sands) will have to be developed at the same time as relatively cheaper but less secure sources. The cost difference per barrel of oil produced from the more expensive and the cheapest sources will then measure the premium placed on the greater supply security of each barrel.

For the low and high extremes, the cost-ranking is not as simple since many of the specified cost-ranges overlap. But it is still clear that the oil sands and frontier oil appear to be the most costly sources, and that there is at least the possibility of upgraded heavy oil or oil from enhanced recovery being slightly cheaper than conventional oil. It should be reiterated, however, that the probability of the extreme low or high estimates is small relative to that of the chosen base case and that they should be viewed only as an indication of possible outside limits for the particular data.

A further observation which can be made in Table 2 is the comparability of supply prices of upgraded heavy oil from enhanced recovery and of upgraded heavy oil from primary and secondary production. It turns out that for the base case these prices differ by $1.33 per barrel with the supply price of the oil from enhanced recovery being lower. One of the reasons for this is that enhanced recovery produces more of the oil in place and thus, although more expensive,

the costs are spread over a greater number of barrels recovered, which lowers the supply price.

The argument for adopting oil self-sufficiency in this country as a worthwhile objective is basically two-fold. Firstly, as a result of the OPEC cartel pricing, imported oil has become very expensive ($35.00/bbl at Montreal) relative to the cost of indigenous production, with no real prospect for a reversal of that trend, and, secondly, although expensive, the supply of imported oil is also rather insecure due to the political instability in the parts of the world where the majority of it comes from. One cannot totally discount the possibility that oil imports might become unavailable at any price if oil is used as a political weapon. Against this background is the fact that in Canada a barrel of oil is currently priced at less than one-half the world price giving consumers totally false price signals about the scarcity of the commodity. If one adds tax and royalty payments to the estimated supply prices in this paper (the base case) and compares them with the current domestic price of oil, only conventional oil production will appear economic, with all others needing the selling price to rise before they would be undertaken. It then seems peculiar that given the low Canadian price, which gives rise to growing demand but provides no incentive for increased domestic production, it is thought that the displacement of imports by increased domestic output is a viable proposition. The objectives of keeping the domestic price from rising and increasing output at the same time are simply not compatible.

From the analysis of this paper, it is clear that increased oil consumption in Canada is being encouraged by a domestic price which is below the cost of providing future supply (the base case) from all sources but one. One of the simplest economic relationships says that as the price of a commodity increases so does supply; and at the same time, consumers cut down or 'economize' the use of it. The application of this simple relationship to the discussed objective of becoming self-sufficient in oil is obvious but its implementation may prove difficult for the political decision-makers in an environment of regulated prices.

Although suggested from the point of view of the basic economic analysis, this paper is not a plea for a quick move of Canadian oil prices to the world levels. In fact the results summarized in Table 2 suggest that since all of the supply prices are well below the world oil price (even if taxes and royalties were added), considerably less than the world price may be needed to bring additional domestic supplies on stream. Increasing the domestic price to the world level would accentuate a revenue distribution problem between the producers and the governments acting on behalf of the society as a whole as the owner of the non-renewable resources.[39]

Ideally, the domestic price and the tax and royalty structure should encourage oil producers to increase supply to the point where the real resource cost (excluding taxes) of an additionally developed pool is just equal to the cost of imported oil plus some premium representing the insecurity of foreign supply. Depending on the actual responsiveness of supply to changes in price, the estimates of supply prices presented in this paper suggest that less than the world price may be needed. How much less is for the industry pricing regulators to decide. The final pricing decisions will have to be based on a more definitive analysis than the present one but as a starting point, the information assembled here should be useful for that purpose.

It should also be remembered that increased domestic prices will have a dampening effect on demand, further improving the prospect of achieving the objective of oil self-sufficiency. If a rising number of Canadian oil producers were offered a higher price for their output, the domestic price paid by the consumers should also be increased to the same level to make such a proposal economically viable from the point of view of the economy as a whole. The working of an ordinary market pricing mechanism is most efficient when consumers are directly charged the full price of a product they buy. The analysis presented here suggests that further delays in implementing a more realistic energy pricing structure in this country will serve only to increase the magnitude of the adjustment problems which Canadian consumers must ultimately face.

Footnotes

[1]R. Uhler, Oil and Gas Finding Costs (Calgary: Canadian Energy Research Institute, Sept. 1979), Study No. 7.

[2]Taking the simple mean of all available estimates to represent the base case can be justified on the basis of giving an equal weight to all sources (except in the case of old data). Any other way of selecting the base case would entail assigning a specific importance to each estimate--presumably in accordance with the source--which for practical purposes is not viewed as superior to the presently used method.

[3]See The Globe and Mail, Jan. 30, 1980, where D. M. McDonald, a director of the Independent Petroleum Association of Canada, called for a higher return to oil producers and stable government policies as means to provide an incentive for finding new oil reserves.

[4]R. Uhler, Oil and Gas Finding Costs; and The Globe and Mail, Oct. 1979. For other estimates of finding costs see The Globe and Mail, Jan. 30, 1980; and Oilweek, Feb. 12, 1979, p. 68. The finding cost for one single year, however, is a difficult concept since reserves discovered in one year may be a result of current expenditures as well as expenditures incurred in the past.

[5]The reason for the inclusion of offshore areas in this estimate is the lack of more disaggregated data.

[6]See Oilweek, Feb. 12, 1979, p. 67. The finding cost estimates include oil as well as natural gas, converted to oil equivalent.

[7]Since two supply estimates (NEB and ERCB) included in this paper are at least two years old, it is possible that the figures in Table 1 are conservative.

[8]Canada, National Energy Board, Canadian Oil Supply and Requirements (Ottawa: National Energy Board, Sept. 1978), p. 33.

[9]Alberta Energy Resources Conservation Board, Forecast of the Supply and Requirements of Crude Oil, Synthetic Crude Oil and Pentanes Plus in Alberta, 1978-1995 (Calgary: Alberta Energy Resources Conservation Board, 1978), pp. 2-2 and 2-3.

[10]For a more detailed breakdown between provinces, see for example the estimates for the period of 1973-1977 in current dollars published in Oilweek, Feb. 12, 1979, pp. 67-68, and Feb. 11, 1980, pp. 48-53. For the purpose of this paper, the Oilweek estimates have been translated into 1980 dollars and are the averages of the three western Canada producing provinces. Other estimates were made available by industry sources or can be found in Canada, NEB, Canadian Oil, p. 41.

[11]See The Globe and Mail, Sept. 26, 1978, for estimates by Dome Petroleum.

[12]The estimate originates with the Energy Division of the Government of Newfoundland. See Canada NEB, Canadian Oil, p. 68.

[13]The Globe and Mail, Feb. 2, 1980.

[14]These figures have been calculated from Oilweek, Feb. 12, 1979, p. 60; and Canadian Petroleum Association, Statistical Handbook (Calgary: Canadian Petroleum Association, 1979).

[15]The figure is based on two estimates, The Globe and Mail, Sept. 26, 1979 ($19.75/bbl in 1985 dollars) and The Calgary Herald, April 20, 1977 ($14.00 to $14.50/bbl in current dollars); and communications with industry sources.

[16]There may possibly be one further complication. The United Nations-sponsored Law of the Sea Conference, currently in session, has not yet resolved one important point concerning exploration efforts in the Canadian frontier. It has not been made completely clear whether an exploiting country would be bound to share some of the discovered oil or gas in fields which cross the 200-mile limit. The Hibernia well is situated 196 nautical miles off Newfoundland. The extent of the oil field is still being determined but it is possible that it (or other fields discovered in the future) may cross the set limit of 200 miles.

[17]The selling price of oil on the world market varies a great deal between exporting countries. The lower price shown here is charged by Saudi Arabia, which exports some 147,400 bbl/day to Canada, while the upper price is charged by Algeria, exporting to Canada some 13,400 bbl/day. For the purpose of calculating the cost of imported oil landed at Montreal, a blend 'world price' is computed according to each country's price and amount of oil it sells to Canada. This price is currently some $35.00/bbl (see The Globe and Mail, April 2, 1980). Canada presently imports about 450,000 barrels of oil per day.

[18]For a basic estimate of the cost of synthetic crude oil, see Canada, Department of Energy, Mines and Resources, Oil Sands and Heavy Oils: The Prospects (Ottawa: Supply and Services, 1977), pp. 16-17 and 31-32.

[19]Canada, NEB, Canadian Oil, pp. 57-62.

[20]Since synthetic crude oil is in fact an upgraded bitumen, as a refinery feedstock it commands a premium of some $1.00/bbl relative to conventional light or medium crude.

[21]The Globe and Mail, April 2, 1980.

[22]The estimates are from the background energy pricing policy documents released by the federal officials before the last First Ministers' meeting on energy pricing. The calculations assume a 2 percent p.a. increase in the world price of oil. See The Globe and Mail, Nov. 9, 1979.

[23]See The Calgary Herald, March 29, 1980, and also The Globe and Mail, Nov. 10, 1979; Jan. 6, 1980; or Oilweek, Jan. 14, 1980.

[24]The first proposal to build a heavy oil upgrading plant of the capacity of 30,000 bbl/d was put forward by Husky Oil in 1975 (see Oilweek, Oct. 11, 1976). The proposal was later changed to a plant capacity of 100,000 bbl/d (The Globe and Mail, Sept. 16, 1978). Other proposals included, for example, Pacific Petroleums' 100,000 bbl/d plant (1978); Petrosar's 100,000 bbl/d plant (1978); and Husky's 50,000 bbl/d plant (1979).

[25]Canada, NEB, Canadian Oil, p. 41. See also Canada, EMR, Oil Sands and Heavy Oils, p. 29, where it is suggested that an optimal size of an upgrading plant is in the order of 100,000 bbl/d but a plant half that size might be economic.

[26]See for example the cost estimates in Canada, NEB, Canadian Oil, p. 41; or Canada, EMR, Oil Sands and Heavy Oils, pp. 29-30.

[27]For the most recent and comprehensive review of these processes, containing a set of cost estimates, see D. B. Black and S. G. Dunn, "An Overview of Commercially Proven Technology for Upgrading Heavy Oils" (Calgary: Associated Pullman-Kellogg Ltd., September 1979). The cost estimates contained in this publication are said to have ±30 percent accuracy.

[28]Much like synthetic crude oil, upgraded heavy oil would be of a higher quality than conventional crude and therefore a more desirable refinery feedstock which could command a premium of up to $1.00/bbl over conventional oil. This would still seem insufficient, however, to change the conclusion of the economic viability of upgraded heavy oil production.

[29]See estimates by Husky Oil relevant to the Lloydminster-type heavy oil in Canada, NEB, Canadian Oil, p. 38.

[30]See the discussion in J. Philip Prince, Conclusions and Policy Implications from Enhanced Recovery Potential in Canada, Study No. 9 (Calgary: Canadian Energy Research Institute, March 1980), pp. 3-4.

[31]J. Philip Prince, Enhanced Oil Recovery Potential in Canada (Calgary: Canadian Energy Research Institute, March 1980), Study No. 9.

[32]ERCB, Forecast, p. 2-9. It turns out, however, that despite this the ERCB forecast is often the lowest of all available sources.

[33]Prince, Conclusions and Policy Implications, p.9.

[34]Ibid, p.4.

[35]Based on Prince, Enhanced Oil Recovery; and industry sources.

[36]See Prince, Enhanced Oil Recovery; and Canada, NEB, Canadian Oil, p. 41, where it is also asserted that the lifting cost of enhanced recovery of heavy oil is about twice as expensive as lifting cost of primary and secondary recovery.

[37]The low and high extremes of this price have been obtained by adding $5.60 to the extreme estimates of heavy oil lifting cost of $5.57 and $11.66.

[38]Based on the findings of Prince, Enhanced Oil Recovery.

[39]Speaking of a non-renewable resource such as crude oil and the desirability of the objective of becoming self-sufficient in its production, one should not forget the old argument which questions the basic wisdom of such an objective. Becoming self-sufficient in the production of a non-renewable resource implies a faster depletion of indigenous reserves and, inevitably, a total dependence on imports once domestic sources have dried up. Postponing the depletion of one's own reserves and increasing imports may, therefore, seem an equally plausible strategy. The extent of the reserves and the rates of depletion will clearly be crucial here, but it seems clear that the objective of oil self-sufficiency will be more effective if it is pursued in order to gain time for the process of substituting (at least to some extent) renewable resources for non-renewable ones.

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